The Athers Controversy Case Study:

A close look at *Athers Food Inc.*'s inventory management policy

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Executive Summary

Background & Aim

Athers Food Inc. as one of the leading food manufacturing companies in the food industry that specializes in canned protein productions, has a well-known reputation for always satisfying demand and keeping high customer satisfaction. However, a recent analysis of the company's demand and inventory tracking reveals that the company is undergoing a process of profit decline, though still earning positive profits. To closely diagnose the potential issue associated with this profit decrease, we aim to conduct a detailed profitability comparison analysis around *Athers Food Inc.*'s profit and cost structures under its current inventory policy and our proposed alternative strategy being guided by the Economic Ordering Quantity (EOQ). Finally, we want to give our recommendation as to how the company should tailor its future operating strategy.

Key Findings

- The demand is increasing each year with an average of 10 units, in addition to the 70 units increase during holiday seasons each year (November & December)
- *Athers Food Inc.* currently implements a variation of the *Periodic-Review Inventory System* with a fixed reordering time at the 10th of each month and a fixed reorder amount of 8,150 for each period
- The huge inventory kept in stock at all times ensures *Athers Food Inc.* never experiences a stockout, but the persistent excess in inventory incurs a large amount of holding cost that leads to a reduction in the company's profitability
- Under the EOQ model with limited flexibility where we cannot reorder before our previou order arrives, we are still able to reduce the holding cost for the company by 20 times compared to its current inventory policy. However, we experience a high ordering cost and high underage cost of missing demand, as the EOQ is small
- With limited flexibility, changing service level does not result in a significant change in the company's total costs and profit
- A fully flexible EOQ model suggests the company should adjust the order gap to 4 days, calculate EOQ using a yearly period, and set the risk level at 0.5

Limitations

- Historical demand assumptions: The recommendations rely on historical data and assumptions about demand patterns, costs, and risk levels
- Market condition changes: The recommendations are tailored for current market conditions
- Implementation challenges: Modifying the order gap, risk level, and EOQ calculation period could necessitate changes in company processes and systems

Introduction

The food industry is considered to be one of the largest and fastest growing sectors that contribute to world economy. Not only does it drives global economic growth, but it also exerts positive impact on job creation and poverty reduction.

Athers Food Inc. is a leading food manufacturing company that specializes in canned protein productions. With a long-established presence in the industry, *Athers Food Inc.* has built a solid supply chain over the decades to eliminate stockout risks. However, recent analysis of the company's annual profit indicates potential problems in its current inventory management system, and *Athers Food Inc.* is now facing the challenge of whether to phase out its current inventory policy to better suit the changing industry landscape.

This report provides a comprehensive analysis of *Athers Food Inc.*'s current inventory policy, identifies any loopholes, and suggests potential tailoring for future strategies. Specifically, we aim to address the following problems:

Problem Statement

- What is the observed demand pattern from 2019 to 2022?
- What is the current inventory policy that *Athers Food Inc.* implements?
- Is the current inventory policy sustainable?
- How would the past and future profits and costs generated under the EOQ model compare to the ones generated from the current policy?
- What are the tradeoffs involved regarding costs and profits after incorporating different levels of stockout risks?
- What is a model with enough flexibility that addresses the problem the company is facing right now?

Analysis

Data

To address the challenges, *Athers Food Inc.* has provided us with data for their *canned protein* spanning from January 1st, 2019 to December 31st, 2021, which contains the date, and the demand and inventory for each day. A snippet of the data is shown in *Table 1.*

Table 1: Sample table for the product data

Day	Demand	Inventory
1/1/2019	340	4660
1/2/2019	336	4324
1/3/2019	177	4147
1/4/2019	172	3975
1/5/2019	513	3462

In addition, we also have the price measurements associated to the company's current inventory system shown in *Table 2*:

Table 2: Relevant margin and costs associated to *Athers Food Inc.*'s inventory management system

Measurement	Dollar amount
Margin	35.5
Setup Cost	1200/batch
Procurement Cost	1.5/unit
Holding Cost	0.25/unit per day

Methods

In order to compare and contrast the impact of the current inventory policy *Athers Food Inc.* implements and the alternative strategy, we aim to calculate the profitability under each and see how they differ. In our analysis, we defined profitability to be that, for each period, the difference between total sales generated by the fulfilled demand and the various costs incurred during this period. More precisely, it is calculated using the following:

$$\begin{aligned}
\text{Profitability in one period} = {} & \text{Fulfilled Demand} \times \text{Margin} \\
& - \text{Setup Cost} \times \text{Number of Replenishment} \\
& - \text{Inventory} \times \text{Holding Cost} \\
& - \text{Procurement Cost} \times \text{Number of Replenishment} \times \text{Replenishment Quantity} \\
& - \text{Underage Cost}
\end{aligned}$$

In this profit calculation, we include the *underage cost* as part of the cost incurred in the inventory system. Underage cost is defined to be the opportunity cost incurred by having lost sales due to understocking, which is a situation where we do not have enough inventory to cover all the demands in that period. The incorporation of underage cost in our profitability calculation lands in a more firm and cautious profit analysis as we incorporated not only the accounting profits but also the economic trade-offs the firm is facing.

Hence, using this profit calculation as a framework, allows us to proceed and compare the profitability under two strategies.

Demand Analysis and Simulation

Before diving into the profit analysis, it is worth noting that *Athers Food Inc.* is not only concerned with how its past profit *would* be under an alternate policy that potentially addresses some of the challenges the firm is facing right now regarding its diminished increase in the annual profitability but also scrutinize the cost and returns in the future under both current strategy and our proposed alternate strategy. With the product data given to us, our first step is to analyze past demand to find any patterns present in the data and, using these patterns, generate our expected demand in 2022 to test our proposed strategies on future profitability. To accomplish this, we would mainly focus on mining the following three trends:

1. How does demand change throughout the year? How does seasonality play a role?
2. Is there an overall change in the demand from year to year?
3. What is the underlying distribution of the demand?

With the above three pieces of information available, we will be able to more accurately simulate demand for the year 2022 to base our profitability analysis.

Profitability Analysis under the Current Policy

With the historical product data given to us, we can calculate the realized profit for the year 2019-2021 and the expected profit using the previous framework. To accomplish this, we also need to first investigate what the current inventory policy for *Athers Food Inc.* is, which would include the following:

1. What inventory system is the firm using, is it *periodic-review system*, *continuous-review system*, or *single-order system*?
2. What is the reorder time and quantity?
3. Does the current inventory system have enough capacity to strategically cover demand? In other words, what are some drawbacks of the current system?

With the above trends identified, we can determine how the current inventory system supports the business, and how it contributes to the current profitability.

Profitability Analysis under EOQ Modelling

After dissecting the profit under the current strategy, we proposed a strategy called *Economic Order Quantity (EOQ)*, which is the optimal quantity to order at each reorder time as an alternate strategy. *EOQ* modeling takes into account the tradeoff between the average ordering cost and average holding cost to find the optimal ordering quantity to minimize the average total cost incurred. We chose this model because it is intuitive, easy to compute, and robust to changes. Furthermore, *EOQ* has the flexibility to incorporate different levels of stockout risks into the modeling to allow us to add safety stocks. The full EOQ model is written out in *Appendix A: Full Model*. After calculating EOQ, we can identify the *reorder point*, which takes into account the lead time and the average demand rate that hints to us on when we should initiate an order to avoid running out of our inventory and losing potential sales.

Results

Demand Analysis

As described previously in the *Methods* section, to analyze the demand pattern to aid in our profit analysis, we plotted the monthly demand for the previous years as shown in *Figure 1*. As the plot shows, in the past three years, there is an overall increase in the monthly demand throughout the years. Moreover, looking more closely at the demand patterns, we spot seasonality, where there is a considerable increase in the monthly demand peaks in November and December, so-called the *holiday seasons*. To more precisely define these increases, we found that: 1. there is an average of 10 units increase in the daily demand in each subsequent year starting from 2019, and 2. during holiday seasons, the daily demand increases by 70 units on average. Next, to investigate the underlying demand distribution, we further overlayed our demand distribution with the density plot for the Negative Binomial distribution with a probability of 5 success and a purchase probability of 2% and found them to be highly similar. For a more detailed introduction to the Negative Binomial distribution and the overlaid plot, refer to *Appendix B: Underlying demand distribution*.

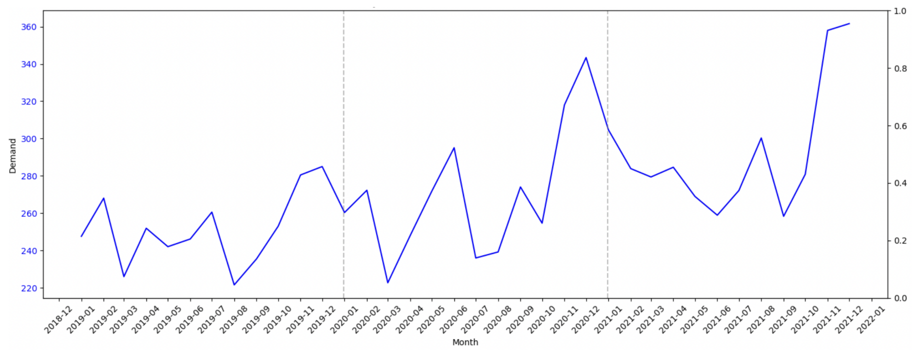

Figure 1: Monthly demand overview from 2019-2021

Current Inventory Policy

Inventory Trend Analysis

After evaluating the demand, we changed our focus to analyze the *Athers Food Inc.*'s current inventory system. As *Figure 2* shows, in the past years, *Athers Food Inc.* kept a significant excessive inventory level (blue line) compared to the actual demand (orange line). Judging by the inventory movement, we can see that they have a fixed restocking window (10th of every month) and fixed order amount (8,150 units). This means that the inventory policy they use is replenishing inventory at a fixed schedule with the same amount. It resembles the *Periodic-Review Inventory System* with one alteration in which the *Athers Food Inc.* orders a fixed amount whereas the periodic review system orders a variable amount depending on the inventory level at that time. With this excess inventory, we further conclude that there has been no unfulfilled demand in the past years, as we always have enough stock to cover the demand. However, even though there are no lost sales, it is likely that *Athers Food Inc.* suffers from the high maintenance cost of always holding this much inventory.

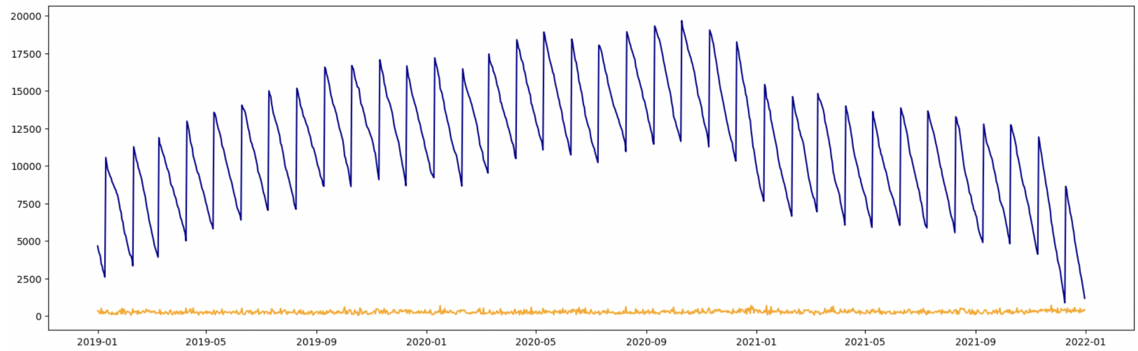

Figure 2: Demand and inventory movement from 2019-2021

Profitability under the current policy

Regarding the periodic review inventory system, two main aspects indicate its unsustainability. Firstly, the inventory began running out at the start of 2022. Over the entire year, the stock ran out 26 times, preventing the company from fulfilling the complete demand of its customers. As a result, only 94% of the required order was satisfied, suggesting that the company may need to reevaluate its current inventory system.

Secondly, while revenue experienced a decline, profit continued to increase. As shown in *Figure 3*, the total profit was roughly 3M, 7% higher than last year, and the total cost was about 500k, 49% lower than last year. However, the inability to meet all customer demands led to missed sales opportunities, resulting in an underage cost of approximately $220k – the first occurrence since 2019. It is important to note that the continued increase in profit stems from cost-saving measures. Lower inventory levels have translated into reduced holding costs compared to previous periods. However, this increased profit is not sustainable in the long run. If the company continues to struggle with insufficient inventory, it risks losing customers and experiencing significant financial losses. Therefore, addressing these issues and improving the inventory management system is crucial to ensure future success.

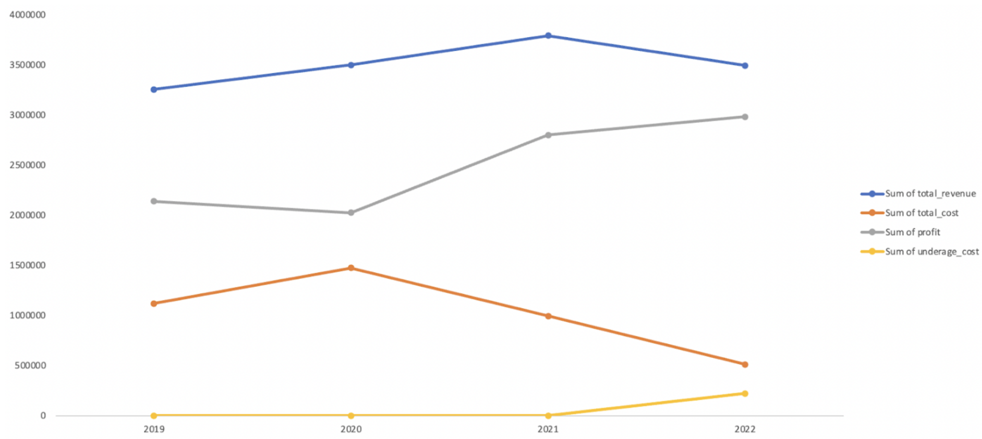

Figure 3: Revenue, Profit, and Cost from 2019 to 2022

EOQ Policy

Profitability in 2019-2021 under the EOQ Policy

Recall the previous inventory trend analysis, the large gap and divergence between inventory level and actual demands pose serious issues regarding the excessive holding costs, which constitutes one of the reasons why despite having a steady increase in demands and revenue, the company still suffered losses in profits. In addition, the current *periodic-review inventory system* with fixed order size is inflexible in dealing with uncertainties in demands as we saw from the holiday hoarding during November and December 2021 where the inventory level dropped significantly and almost resulted in a stockout. To ameliorate these shortcomings in the current model, one could instead apply the *Economic Order*

Quantity Model (EOQ) with *Reorder Point (ROP)* to introduce more flexibility and regulate order size. Based on the average demand and holding costs given a selected period, we can calculate the optimal order quantity using the EOQ model. Furthermore, the introduction of ROP sets up a "trigger" inventory level at which a company has to make a reorder to ensure the satisfaction of daily demand during the lead time. As a result, the inventory system becomes a *continuous-review system* due to the existence of trigger inventory level ROP. Note, for model demonstration purposes, we assume that we do not make any additional orders during the lead time. This constraint will be lifted once we enter the more flexible variation of this model in the later section.

After incorporating the new inventory system into the 2019-2021 data, we were able to generate the daily inventory level and use them to conduct a profitability analysis. In our setting, three cost items were considered, the holding cost, the ordering cost (set-up cost), and the underage cost. Note, the underage cost is not embedded in the EOQ model setting but it is a crucial component to consider when optimizing inventory systems and maximizing profit. Refer to the *Table 3* for the original profitability breakdown and *Table 4* for the breakdown under the EOQ policy:

Table 3: Under current inventory system (periodic-review with fixed order size)

Year	**Holding Cost**	**Order Cost**	**Production Cost**	**Underage Cost**	**Total Cost**	**Total Revenue**	**Economic Profit**
2019	\$956,871	\$14,400	\$146,700	\$0	\$1,117,971	\$3,256,841	\$2,138,869
2020	\$1,313,014	\$14,400	\$146,700	\$0	\$1,474,114	\$3,501,152	\$2,027,037
2021	\$831,750	\$14,400	\$146,700	\$0	\$992,850	\$3,793,388	\$2,800,538

Table 4: Under EOQ (continuous-review with optimal Q and reorder point ROP)

Year	**Holding Cost**	**Order Cost**	**Production Cost**	**Underage Cost**	**Total Cost**	**Total Revenue**	**Economic Profit**
2019	\$54,529	\$46,800	\$90,909	\$93,6987	\$1,129,225	\$2,319,854	\$1,190,630
2020	\$42,924	\$49,200	\$98,954	\$1,177,003	\$1,368,080	\$2,324,150	\$956,070
2021	\$42,931	\$48,000	\$100,620	\$1,385,139	\$1,576,690	\$2,408,249	\$831,559

- Larger Value - Lower Value

From the above two tables that summarize the cost-revenue breakdown for each inventory system across 2019 to 2021, one salient difference is the holding cost. The holding cost for the current inventory system is more than 20 times higher than the EOQ model. Since the company tends to order more frequently with a lower order size (determined by the optimal quantity. In this case, the optimal quantity ranges from 1554 to 1667 which is much lower than the current fixed amount of 8150 units) using the EOQ model, the order cost (set up cost) will be higher but the production cost will be lower. Another significant difference is the underage cost gap which resulted from stockout under the EOQ model. The stockout was caused by the relatively small order quantity and inability to accumulate inventory due to our previous assumption of not ordering during lead time.

Continuing with our reasoning on the underage cost, if we only consider the accounting profit which only considers revenue and explicit costs, we would have a different cost-revenue summary as shown in *Table 5*:

Table 5: Cost and revenue summary accounting for underage costs

Year	**Profit Margin (current)**	**Profit Margin After Underage (EOQ)**	**Profit Margin Before Underage (EOQ)**
2019	65.67%	51.32%	91.71%
2020	57.90%	41.14%	91.78%
2021	73.83%	34,53%	92.05%

From the accounting profit perspective, the profit margins when adapting the EOQ model exceed the incredible 90% mark due to mass holding cost reduction. However, it does not present the whole story to us regarding the increased stockout periods that could potentially jeopardize the business in a profound way. Once we calculate the after-underage profit margins for the EOQ model, we see that the numbers dropped significantly as the demand increases because we are missing out on the demand growth and not realizing the sales.

In conclusion, although the EOQ model with ROP has the potential to manage inventory level more efficiently and reduce costs, the current model we presented were unable to satisfy demands which resulted in stockout periods and still fall short in dealing with uncertainty in demands. As a result, it has motivated us to further adjust the model to make it more resilient to uncertainties.

Envisioned Profitability in 2022 under the EOQ Policy

Before we move forward to demonstrate tradeoffs in choosing different service levels to mitigate stockout risks, we also looked at the cost-revenue comparisons between using the current inventory system and the EOQ model for the simulated 2022 data. We can see that the previously determined patterns persisted with increased magnitude, a result of the consistently growing demand.

Table 6: Profitability breakdown comparison for 2022 under the current and the EOQ policy

	Holding Cost	**Order Cost**	**Production Cost**	**Underage Cost**	**Total Cost**	**Total Revenue**	**Economic Profit**
Current	$349,154	$14,400	$146,700	$220,349	$730,602	$3,495,436	$2,764,834
EOP	$42,638	$49,200	$102,090	$1,327,026	$1,520,953	$2,388,759	$867,805

Impact of Adding Safety Stock at Different Service Level on Profit

Based on the initial analysis conducted, we concluded that for the years 2019, 2020, and 2022 a risk level of 0% leads to the highest profit. This finding is consistent with a previous analysis that showed the company's current strategy is more profitable than the Economic Order Quantity (EOQ) strategy. The reason is that the holding cost is much lower than the sales margin. Therefore, the probability of having stockouts is more costly for the company than holding more inventory and never having stockouts. However, for 2021, the analysis showed that the maximum profit occurs at a risk level of 0.5%, which implies that the optimal risk level may vary depending on the year and demand. We recommend that the company continuously monitors the market conditions and adjusts its inventory management strategy accordingly to maximize profits. *Table 7* displays the costs and risk level for each year associated with the highest total profits. Additionally, *Appendix B: Risk vs. Costs* and *Appendix B: Risk vs. Profit* contain plots regarding the change in total costs and profits based on different service risk levels. We see there is not a significant change in the costs and profit regardless the risk level we specify, meaning adding safety stock in this case in the attempt to reduce stockout times is not a viable solution.

To diagnose more of the observation, upon closer examination, we discovered that the reorder point for the EOQ is not sufficient, and we are constantly experiencing stockouts due to the long lead time and small EOQ. At this point, the service level becomes less important because the profit and cost are dependent on the stock out. Although the trend appears to be driven by the service level, it is dictated by the underage. The slight differences in the results are due to changes in the safety stock at the beginning, but as stockouts occur, the service level is no longer helpful. The inventory behaves in the same way as before, suffering significant losses from the stockout.

Table 7: Total costs and profits under the specified stock-out risk level that gives the highest profit for each year

Year	**Total Cost**	**Total Profit**	**Risk Level**
2019	$199,270	$2,137,978	0.0%
2020	$186,996	$2,144,714	0.0%
2021	$194,684	$2,246,189	50.0%
2022	$188,288	$2,187,620	0.0%

Adding Flexibility to our Model to Guide the Optimal Strategy

In the previous model, the company still faced stockouts due to the limitation that it could only order at specific times. Suppose the ordering time limitation does not constrain the company, and it is free to order anytime. We design this approach by changing the *order gap* in the model. For example, if the *order gap* is 5, the company can place the next order five days after the current order. In this way, we can help the company find the changes in cost and profits by adjusting the different levels of the *order gap*.

Figure 4 shows that the company reached its highest economic profit ($3.25M) when the *order gap* was 4, assuming the risk level was set at 0.05 and the period for calculating EOQ is one year. There were a few factors that influenced the best *order gap*. Firstly, the underage cost was the lowest when the *order gap* was 4, meaning there were no unfulfilled orders, and consequently, the company could achieve the maximum revenue it could earn. Secondly, the underage cost was more expensive than the holding cost. The model determined the optimal *order gap* that maintained an appropriate inventory level while minimizing the underage cost. If the *order gap* is larger than 4, the company may sacrifice a significant amount of underage cost by benefiting from a slight decrease in holding cost. In addition, smaller order gaps may incur higher setup costs and unnecessarily high holding costs.

Overall, we also optimized the model by changing the *order gap*, risk level, and period values for calculating EOQ. The objective is to maximize the economic profit by deducting the total selling-related and underage costs from revenues. In the end, the optimal *order gap* is 4, meaning the company should order the next order after four days of the current one. The optimal period for calculating the EOQ is one year due to the less variability of the yearly demand. The optimal risk level is 0.5, meaning the company does not need the safety stock. Since the company is free from ordering time limitations, there is no need to require the safety stock, which may cause unnecessary holding costs.

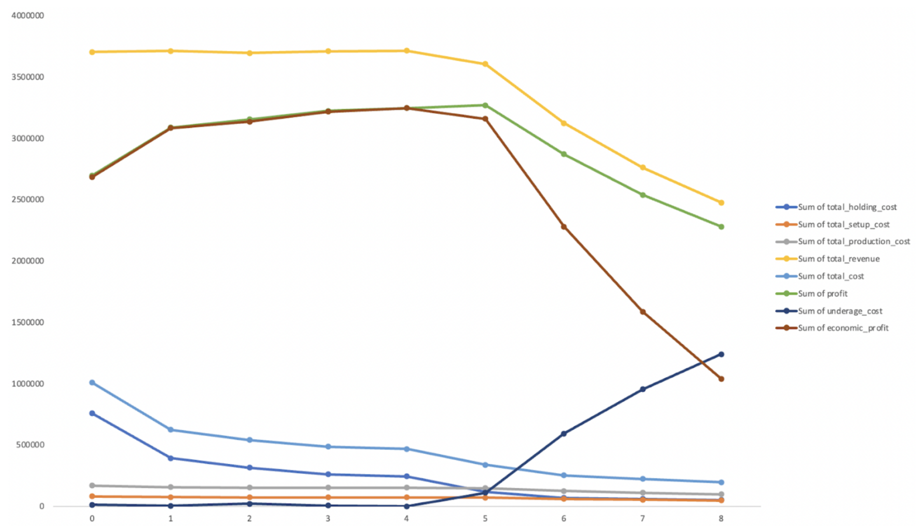

Figure 4: Revenue, Cost, and Profit by Order Gap in 2022

Conclusion

Summary

This report is a comprehensive analysis of *Athers Food Inc.*'s current inventory policy, which specializes in canned protein production. it includes an analysis of the data provided which spans from January 1st, 2019 to December 31st, 2021, and contains the date, demand, and inventory for each day. The report also presents a profitability analysis under the current policy and the Economic Order Quantity (EOQ) policy, which is the optimal quantity to order at each reorder time as an alternate strategy. The EOQ model takes into account the tradeoff between the average ordering cost and average holding cost to find the optimal ordering quantity to minimize the average total cost incurred. The report concludes with the results of the demand analysis and simulation, the profitability analysis under the current policy, and the EOQ policy.

Recommendations & Future Steps

Based on our analysis, we recommend the following actions for the company to optimize its inventory management:

1. Adjust the order gap to 4 days: The company should place the next order four days after the current one. This order gap will help the company maintain an appropriate inventory level while minimizing underage costs and achieving maximum revenue.

2. Calculate EOQ using a yearly period: The optimal period for calculating the EOQ is one year due to the less variability in annual demand.

3. Set the risk level at 0.5: The optimal risk level is 0.5, which indicates that the company does not need to maintain safety stock. Since the company is no longer constrained by ordering time limitations, there is no need to require safety stock, which may lead to unnecessary holding costs.

By implementing these recommendations, the company can improve its inventory management system, reduce costs, and increase profitability. It is essential to continuously monitor and adjust these parameters to respond to changes in demand patterns or market conditions.

Limitations

Before closing the report, we want to point out some potential limitations of our analysis. Firstly, the recommendations are based on historical data and assumptions about demand patterns, costs, and risk levels. The advice may not yield optimal results if the actual data or market conditions differ from these assumptions. Moreover, the recommendations are optimized for the current market conditions. However, market conditions may change, leading to demand, costs, or lead times fluctuations. In such cases, the company should re-evaluate and adjust its inventory management strategies accordingly. Lastly, adjusting the order gap, risk level, and EOQ calculation period may require company processes and systems changes. These changes might encounter resistance or operational challenges, affecting the implementation of the recommendations.

Appendix

A

Full Model

$$\min_Q E(C) = (\frac{E[D]}{Q})S + (\frac{Q}{2} + ss)H + pE[D]$$

where:
Q : EOQ, our optimal quantity to order in each reorder period
$E[C]$: Expected costs, the value we try to minimize
$E[D]$: Expected demand in the period
S : Setup cost
H : Holding cost for per unit inventory per unit of time
p : Purchase price of each product
ss : Units of safety stock
Solving the above equation, we would obtain our EOQ as the follows:

$$Q_{optimal} = \sqrt{\frac{2 \times E[D] \times S}{H}}$$

B

Underlying demand distribution

Negative Binomial distribution (*Negative Binomial(r,p)* is a discrete probability distribution that is the sum of independently and identically distributed Bernoulli trials. This distribution tries to model the probability of having a different number of failures before reaching a certain number of success trials (r) given the probability of a success trial being p. To model our demand, we assembled demand using a *Negative Binomial(5, 0.02)*, which models the probability of having 5 purchases with a purchase probability of 0.02.

With the specified distribution, we overlaid the observed demand in 2019 with the density plot of *Negative Binomial(5, 0.02)* as shown in *Figure 5*. We see that the observed demand closely assembles the Negative Binomial distribution with slight deviations.

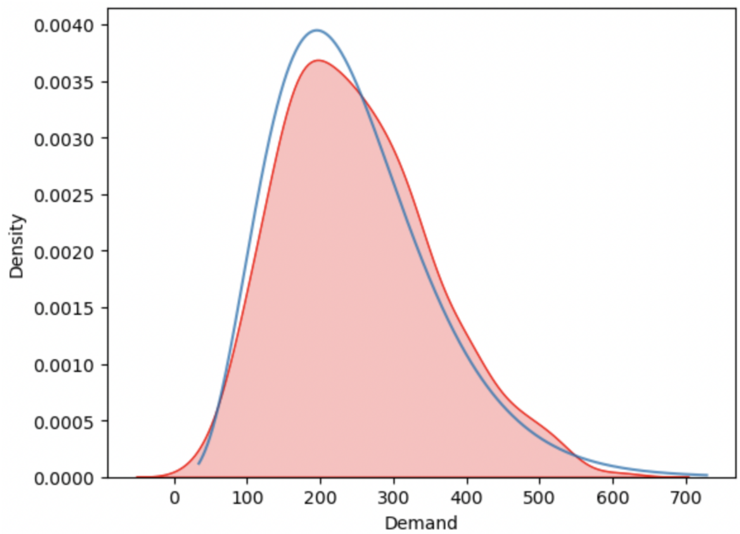

Figure 5: Observed demand distribution in 2019 overlaid with Negative Binomial(5, 0.02)

Risk vs. Costs

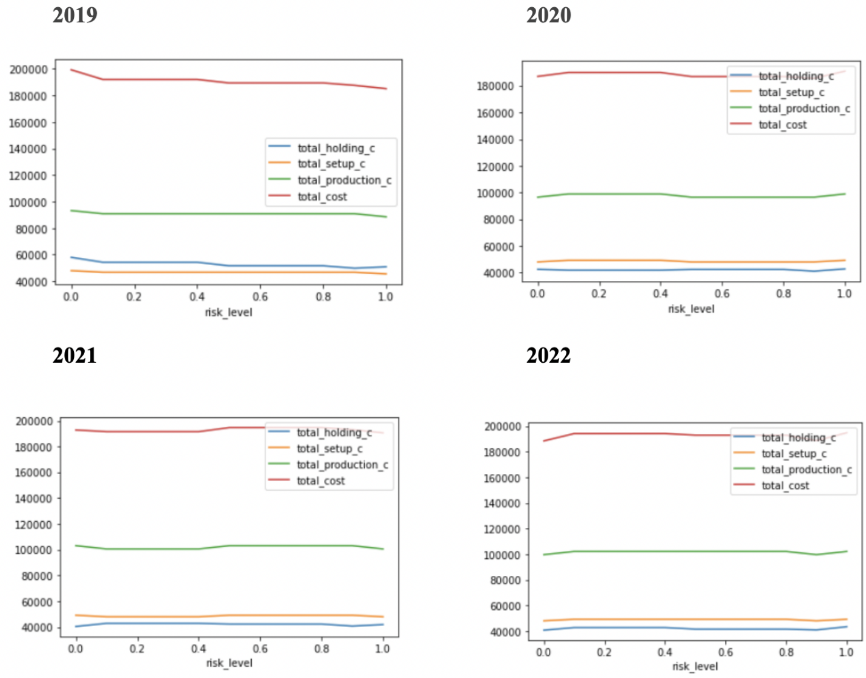

Figure 6: Various costs under different risk levels for each year

Risk vs. Profit

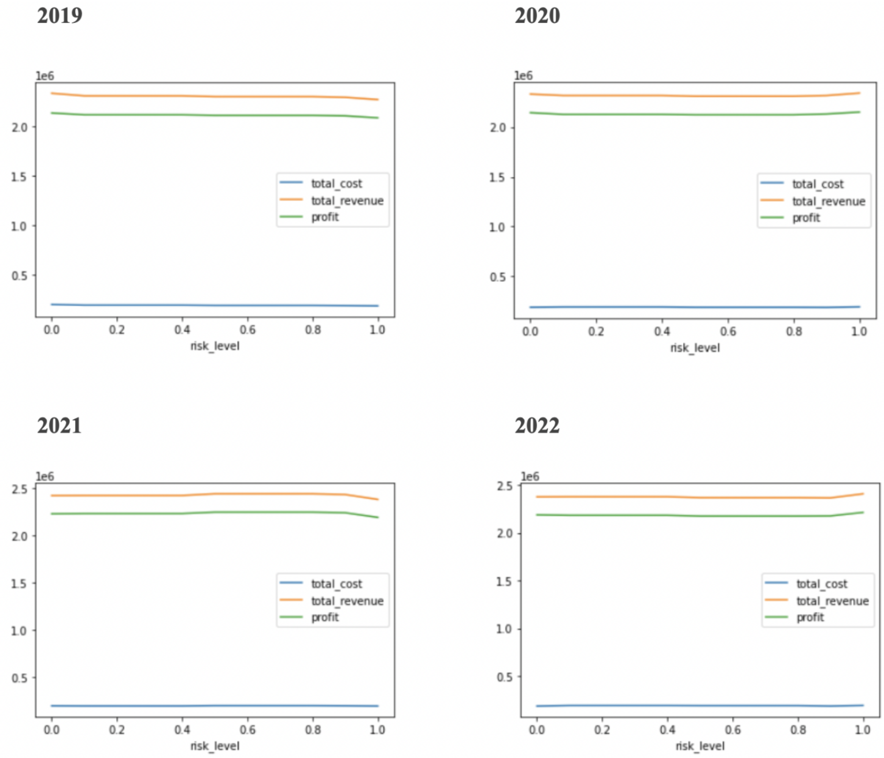

Figure 7: Total costs, revenue, and profit under different risk levels for each year